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Effect of leg length discrepancy on the difference of lateral center-edge angle measurement

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미치는 영향

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Abstract

Effect of leg length discrepancy on the difference of lateral center-edge angle measurement

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Aims

Lateral center-edge angle (LCEA) is a widely used radiographic parameter for measuring the acetabular coverage of the femoral head. In patients with leg length discrepancy (LLD), due to the pelvic obliquity in coronal plane, the LCEA is differently measured according to which longitudinal reference line is used. The aims of this study were to inspect which reference line has been used for measuring the LCEA in the literature, and to validate Morscher's method to estimate the difference of LCEA on the longitudinal reference lines in the patients with LLD.

Patients and Methods

Clinical studies involving LCEA between January 1976 and July

2019 in MEDLINE database were categorized according to the longitudinal reference line used. From January 1, 2004 to July 23, 2019, 238 patients who were surgically treated for LLD were recruited for the study. The LCEA was measured on standing pelvis anteroposterior radiograph using two different longitudinal axes– the longitudinal axis of pelvis (pLCEA) or the line vertical to the ground (gLCEA) on the shorter leg. Difference between the two LCEA (dLCEA) was calculated. dLCEA was also estimated using Morscher's trigonometric equation from the pelvic width and leg length discrepancy measured on the same pelvic radiograph. The measured and estimated dLCEAs were compared.

Results

Among 172 articles, pLCEA and gLCEA were used in 18 (10%) and 13 (8%). 108 (63%) studies cited the relevant reference without specifying the measurement method of LCEA in the manuscript, whereas 33 (19%) did not include either the method of measurement or the citation of reference on LCEA. The pLCEA (26.8 ± 6.8°, [range, 2.6° to 52.2°]) and the gLCEA (36.0 ± 8.0°, [range, 8.2° to 58.2°]) showed significant difference with the mean dLCEA of 9.1 ± 4.6° [range, 0.7° to 26.1°]. The pelvic width of the study patients was 174.3 ± 24.3mm (range, 120.0 to 235.8mm) and

it showed linear increase with age until the age of 15 years. The mean value of dLCEA estimated with Morscher's method was 9.2 ± 4.6° [range, 1.0° to 26.1°], which showed no significant difference from the measured dLCEA (p=0.433).

Conclusion

Because the pLCEA and gLCEA are different in patients with LLD, which reference line was used in measuring the LCEA needs to be described in the article. In patients with LLD, Morscher's method of estimating the dLCEA was successfully validated. This information could be used for treating the patients with LLD by estimating the change of LCEA with LLD and pelvic width.

Keywords : **leg length discrepancy, lateral center-edge angle, statistical validation**

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Introduction

1.1. Study Background

Lateral center−edge angle (LCEA) is a radiographic parameter measuring the femoral head coverage by the acetabulum which is widely used in making diagnosis, deciding the treatment plan, and assessing the treatment outcomes in various hip diseases.(1) The LCEA, introduced by Wiberg in 1939, is defined as an angle formed by two lines running from the center of the femoral head, one through the lateral edge of the acetabulum and the other parallel with the longitudinal axis of the body.(2) However, the exact definition of the longitudinal axis of the body for measuring the LCEA was not made in his study.(2)

In patients with leg length discrepancy (LLD), the pelvis is rotated in coronal plane on standing position, resulting in a condition called pelvic obliquity. When the pelvic obliquity is present, the spine compensates and restores the longitudinal axis of body above the pelvis to be vertical to ground. In such patients, either the longitudinal axis of pelvis or a line vertical to the ground may be used as the longitudinal reference line in measuring LCEA, and the value of the LCEA will differ depending on which reference line was used. This makes accurate comparison of the results between studies difficult. Considering the high prevalence of LLD and the frequent use and clinical importance of the LCEA, it is necessary to investigate the effect of LLD on the difference of the LCEA measurement. The acetabular dysplasia on the longer leg caused by acetabular undercoverage due to pelvic obliquity is clinically important since acetabular dysplasia is reported to be related to the development of early osteoarthritis of hip.(3−5)

In 1977, Morscher suggested that there is approximately 4.5° of diminution of LCEA on the longer leg with 2cm of LLD.(6) This correlation was calculated by trigonometric equation in a pelvis whose width was 25cm. Although the exact definition of vertical reference line was not made in his study, LCEA was measured with the longitudinal axis vertical to ground as the LCEA measured with longitudinal pelvic axis would be constant regardless of LLD. However, aforementioned correlation between LCEA change and LLD holds only when the pelvic width is 25cm.

1.2. Purpose of Research

The purposes of this study were to systematically inspect which reference line has been used for measuring the LCEA in previous studies, and to validate Morscher's method to estimate the difference between two LCEAs.

Materials and Methods

This literature review and retrospective study was approved by the institutional review board.

2.1. Literature review

Clinical studies published between January 1976 and July 2019 in MEDLINE database were searched. Search terms included: “center−edge angle”, “center edge angle”, “CE angle”, and “CEA”. The search was restricted to English language publications in *The Bone & Joint Journal*, *The Journal of Bone & Joint Surgery British Volume, The Journal of Bone & Joint Surgery American Volume,* and *Clinical Orthopaedics and Related Research*. The complete search strings are shown in the Supplementary material 1. Unpublished data, letters to editor, and instructional courses were not included.

The searched literatures were categorized into three groups; the studies using the longitudinal axis of the pelvis as a reference line, the studies using the line vertical to the ground and the studies that did not specify which reference line was used. The studies which cited Wiberg’s original article(2) when stating LCEA were included in the third group.

2.2. Patients

A query was performed on an orthopaedic departmental database at a single tertiary−care center to identify all patients who were surgically treated for LLD between January 1, 2004 and July 23, 2019. Only the patients who were older than 5 years at the time of operation were included because incomplete ossification of capital femoral epiphysis might affect the measurement of LCEA.(7) Patients whose standing pelvis radiograph was inappropriately taken or unavailable, and who had proximal femoral deformity, contractures in hip, knee, or ankle joints were excluded. The appropriateness of standing pelvis radiographs was assessed with the symmetricity of both obturator foramen and the distance from symphysis pubis to the tip of coccyx.(8, 9) On the basis of these criteria, 238 patients were included in this study (Fig. 1)

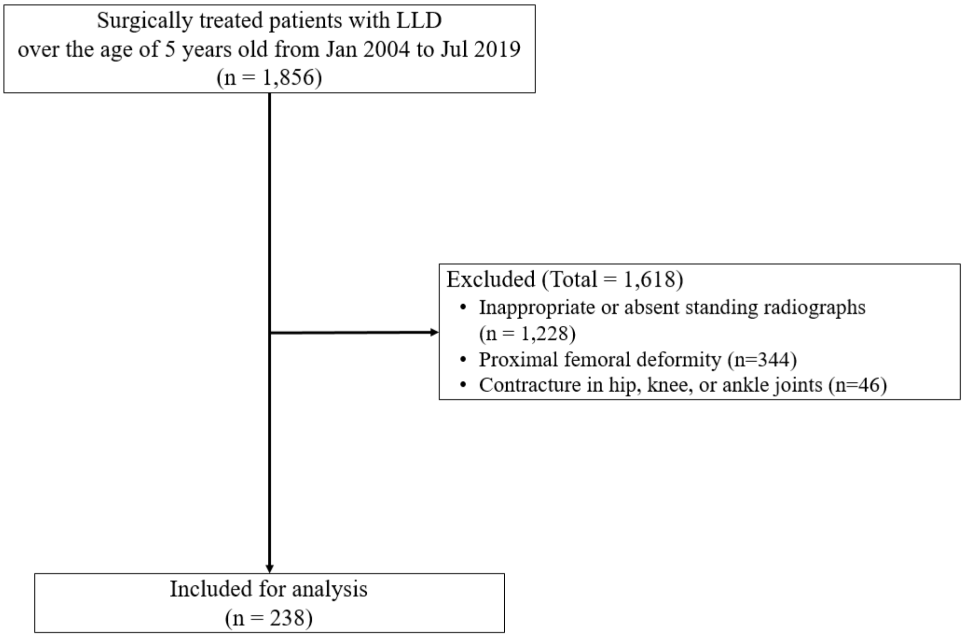

Fig. 1. Flowchart of the study population

There were 123 males (52%) and 115 females (48%). The mean age was 13.0 ± 5.2 years (range, 5 years to 37 years) at the time of measurement (Table 1). Radiographic assessments were made in standing anteroposterior pelvic radiographs. On standing anteroposterior pelvic radiographs, LCEAs depending on two different longitudinal reference lines, LLD, and pelvic width were defined. A line vertical to the line connecting the center of both femoral heads was defined as the longitudinal axis of the pelvis.(5, 10) Therefore, the pLCEA was defined as the angle formed by two lines running through the center of femoral head: one through the lateral edge of acetabulum and the other perpendicular to the line connecting the center of both femoral heads. The gLCEA was defined as the same way with the longitudinal reference line vertical to the ground. The LLD was defined as the vertical distance between the two femoral heads center, and the pelvic width as the shortest distance between them.(6) (Fig. 2) The pLCEA, gLCEA, LLD, and pelvic width were measured on shorter leg. To compare intraobserver reliability, above four radiographic parameters were measured on the shorter leg twice two weeks apart. To compare interobserver reliability, the same parameters were measured by other orthopedic surgeon (C.H.S.) after reaching a consensus on the measurement method.

Table 1. Patient demographics

Characteristics	Value
Age at measurement, years Mean ± S.D. (range)	12.1 ± 3.9 (5.0 to 37.0)
Sex (male : female), n (%)	123 (52) : 115 (48)
Height, cm (range) Mean ± S.D. (range)	143.2 ± 22.7 (81.0 to 182.1)
Laterality (shorter leg, right : left) n (%)	96 (40) : 142 (60)

LLD, mm (range) Mean ± S.D. (range)	27.2 ± 13.1 (2.7 to 83.0)
Pelvic width, mm (range) Mean ± S.D. (range)	174.3 ± 24.3 (120.0 to 235.8)

LLD: Leg length discrepancy; S.D.: standard deviation

2.3. dLCEA measured on radiograph vs. dLCEA estimated from Morscher's equation

The dLCEA was defined as the difference between pLCEA and gLCEA, and the measured dLCEA (mdLCEA) was obtained by subtracting pLCEA from gLCEA. The estimated dLCEA (edLCEA) was calculated from pelvic width and LLD using the Morscher' s method (6).

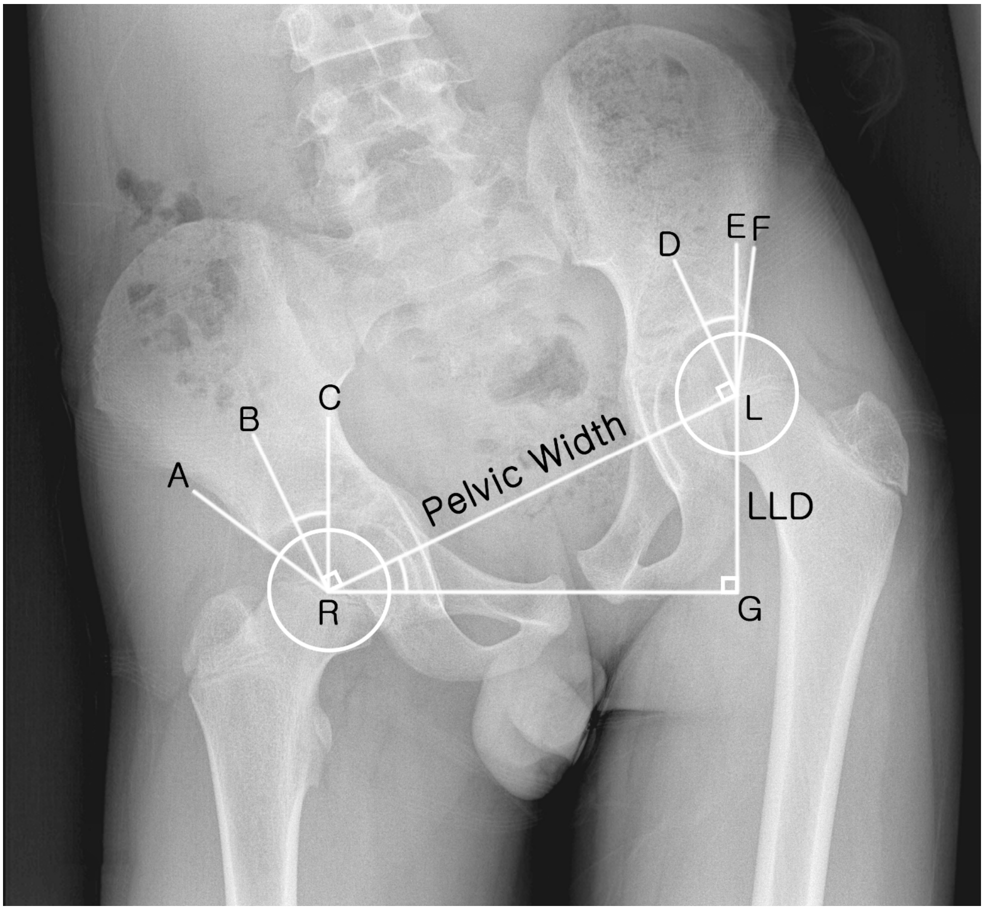

Fig. 2. A schematic figure of the pelvis of a patient with LLD. R and L are centers of both femoral heads. Lines CR and EL are vertical to the ground, and lines BR and DL are vertical to the pelvis. Line GL and RL are LLD and the pelvic width, respectively. As dLCEA is equal to the angle LRG, sin (dLCEA) is equal to LLD divided by pelvic width. LCEA, lateral center edge angle; LLD, leg length discrepancy. (Figure modified from Morscher, Prog Orthop Surg. 1977)

The change of LCEA in patients with LLD presented by

Morscher corresponds to the dLCEA in this study. The edLCEA from LLD and pelvic width was acquired from Morscher' s method derived from triangle RLG. (Fig. 2). As pLCEA is angle ARB and gLCEA is angle ARC, dLCEA corresponds to angle BRC. As the dLCEA is the difference between pLCEA and gLCEA, it is essentially same as the angle formed by the two longitudinal reference lines. Line RL represents the pelvic axis while the line RG represents the line parallel to ground. Therefore, the dLCEA is same as the angle LRG, which is an angle formed by the two lines vertical to the two longitudinal reference lines. If we measure LLD and pelvic width, dLCEA is calculated as the following equation.(6)

$$\sin(\mathrm{dLCEA}) = \frac{\mathrm{LLD}}{\text{pelvic width}}$$

$$\mathrm{dLCEA} = \arcsin\left(\frac{\mathrm{LLD}}{\text{pelvic width}}\right)$$

To validate Morscher' s method in patients with LLD, the edLCEA calculated in each patient was compared with mdLCEA with Wilcoxon signed-rank test.

2.4. Pelvic width in the current study subjects

Normality of the pelvic width distribution in the study subjects was assessed. The relationship between age and pelvic width, and that between gender and pelvic width were analyzed. As the size of the pelvis is reported to grow until the skeletal maturity, the patients were divided into two groups; before and after the arrival of plateau of pelvic width and analyzed separately.

2.5. Statistical analysis

The values of pLCEA and gLCEA on the shorter leg were compared using paired *t*−test. The normality of pelvic width was evaluated with Kolmogorov−Smirnov test. The relationship between age and pelvic width was assessed with regression analysis in two separate age groups. The relationship between gender and pelvic width was evaluated with student’s *t*−test. A sample size of 54 patients was required to detect a difference of 2° between the edLCEA from Morscher’s method and mdLCEA, using Wilcoxon signed−rank test with a power of 80% at a level of significance of $p < 0.05$.(10) To find the correlation of the difference between edLCEA and mdLCEA and gLCEA, pLCEA, LLD, or pelvic width, Pearson’s correlation coefficients were used.

Reliability of measurement of pLCEA, gLCEA, LLD, and pelvic width was respectively assessed with intraobserver and interobserver repeatability which were presented as intraclass correlation coefficient (ICC) (absolute−agreement−type, double−measurement, 2−way random−effect model). The interpretation of intraclass correlation coefficient was as follows: minimal <0.2, poor 0.2~0.4, moderate 0.4~0.6, strong 0.6~0.8, and almost perfect >0.8.(11)

Results

3.1. Literature review

A total of 172 articles were included in the literature search. The number of papers from *The Bone & Joint Journal (The Journal of Bone & Joint Surgery British Volume), The Journal of Bone & Joint Surgery American Volume,* and *Clinical Orthopaedics and Related Research* was 12, 52, and 108, respectively. The reference line used in measuring the LCEA was specified in 31 articles (18%). The longitudinal axis of the pelvis, i.e. pLCEA was used in 18 (10%) studies, whereas the line vertical to the ground, i.e. gLCEA was used in the other 13 (8%) studies as a reference line. Among the rest 141 articles which did not elaborate on the specific measurement method of LCEA, 108 studies (63%) cited the relevant reference, which did not specify whether pLCEA or gLCEA were used as LCEA. The other 33 (19%) studies did not cite any reference regarding LCEA. The specific lists of literatures categorized according to the measurement method of the LCEA are shown in the Supplementary material 2.

3.2. Comparison of the estimated dLCEA with the measured dLCEA

The gLCEA (36.0 ± 8.0°, [range, 8.2° to 58.2°]) measured on radiograph was significantly larger than the pLCEA (26.8 ± 6.8°, [range, 2.6° to 52.2°]) on shorter legs ($p<0.001$). The mean mdLCEA was 9.1 ± 4.6° [range, 0.7° to 26.1°], and the mean edLCEA was 9.2 ± 4.6° [range, 1.0° to 26.1°], which was not significantly different by Wilcoxon signed-rank test ($p=0.433$). The edLCEA from given LLD and pelvic width by Morscher's method is summarized in Table 2. The range of pelvic width given in Table 2 was based on the range of pelvic width of the current study patients. The difference between edLCEA and mdLCEA showed no correlation with gLCEA ($p=0.420$), pLCEA ($p=0.712$), LLD ($p=0.701$), or pelvic width ($p=0.086$). All the four measured parameters, gLCEA, pLCEA, LLD, and pelvic width showed almost perfect ICC (Table 3). LLD showed the highest ICC followed by pelvic width, pLCEA and gLCEA in the intraobserver and interobserver reliability test.

Table 2. Estimates of dLCEA by LLD and pelvic width on the shorter leg

Pelvic width (mm)	LLD (mm) 10	15	20	25	30	35	40	45	50
100	5.7°	8.6°	11.5°	14.5°	17.5°	20.5°	23.6°	26.7°	30.0°
110	5.2°	7.8°	10.5°	13.1°	15.8°	18.6°	21.3°	24.1°	27.0°
120	4.8°	7.2°	9.6°	12.0°	14.5°	17.0°	19.5°	22.0°	24.6°
130	4.4°	6.6°	8.8°	11.1°	13.3°	15.6°	17.9°	20.3°	22.6°
140	4.1°	6.2°	8.2°	10.3°	12.4°	14.5°	16.6°	18.7°	20.9°
150	3.8°	5.7°	7.7°	9.6°	11.5°	13.5°	15.5°	17.5°	19.5°
160	3.6°	5.4°	7.2°	9.0°	10.8°	12.6°	14.5°	16.3°	18.2°
170	3.4°	5.1°	6.8°	8.5°	10.2°	11.9°	13.6°	15.3°	17.1°
180	3.2°	4.8°	6.4°	8.0°	9.6°	11.2°	12.8°	14.5°	16.1°
190	3.0°	4.5°	6.0°	7.6°	9.1°	10.6°	12.2°	13.7°	15.3°
200	2.9°	4.3°	5.7°	7.2°	8.6°	10.1°	11.5°	13.0°	14.5°
210	2.7°	4.1°	5.5°	6.8°	8.2°	9.6°	11.0°	12.4°	13.8°
220	2.6°	3.9°	5.2°	6.5°	7.8°	9.2°	10.5°	11.8°	13.1°
230	2.5°	3.7°	5.0°	6.2°	7.5°	8.8°	10.0°	11.3°	12.6°
240	2.4°	3.6°	4.8°	6.0°	7.2°	8.4°	9.6°	10.8°	12.0°
250	2.3°	3.4°	4.6°	5.7°	6.9°	8.0°	9.2°	10.4°	11.5°
260	2.2°	3.3°	4.4°	5.5°	6.6°	7.7°	8.8°	10.0°	11.1°

dLCEA, difference between lateral center−edge angle measured with the longitudinal reference line vertical to ground and longitudinal reference line vertical to the line connecting two femoral head centers; LLD, leg length discrepancy

Table 3. Intraclass correlation coefficients to evaluate intraobserver and interobserver reliability

Parameters	Intraobserver (95% CI)	Interobserver (95% CI)
gLCEA	0.921 (0.913 to 0.978)	0.896 (0.220 to 0.968)
pLCEA	0.926 (0.865 to 0.957)	0.927 (0.421 to 0.977)
LLD	0.976 (0.962 to 0.981)	0.968 (0.945 to 0.981)
Pelvic width	0.943 (0.912 to 0.963)	0.938 (0.905 to 0.960)

gLCEA, lateral center-edge angle measured with the longitudinal reference line vertical to the ground; pLCEA, lateral center-edge angle measured with the longitudinal reference line vertical to the line connecting two femoral head centers; LLD, leg length discrepancy

3.2. The pelvic width in Korean patients with LLD

The measured values of pelvic width in the study subjects showed normal distribution with p = 0.200 in Kolmogorov−Smirnov normality test. The mean value of pelvic width was 174.3 ± 24.3mm (range, 120.0 to 235.8mm). The pelvic width increased until the age of 15 and showed no significant change afterwards (Fig. 3A). Therefore, we divided the study patients into two groups: one consisted of the patients with age from 5 to 15 and the other consisted of those with age over 15 years. The first and second group included 215 and 23 patients respectively. In the first group, regression analysis showed the relationship between age and pelvic width could be estimated as following equation in pediatric patients with LLD in Korean population ($R^2 = 0.615$, $p<0.001$).

$$\text{Pelvic width (mm)} = 8.04 \times (\text{age (year)}) + 81.49$$

In the second group, both regression and correlation analysis showed no significant relationship between age and pelvic width ($p = 0.963$). The mean pelvic width in men was 177.9 ± 22.8mm while that in women was 170.4 ± 25.4mm. There was statistically significant difference of pelvic width between men and women ($p = 0.017$). For both groups of men and women, scatter plots of age against pelvic width showed the tendency of increase of pelvic width until the age of 15 years and then forming a plateau as in the first age group (Fig. 3B, Fig. 3C).

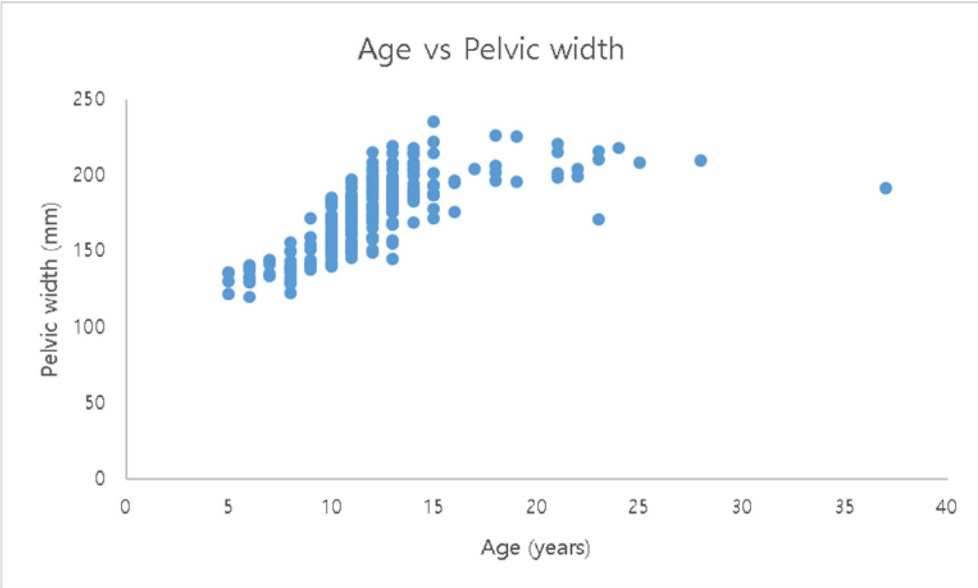

Fig. 3A. The scatter plot of age versus pelvic width

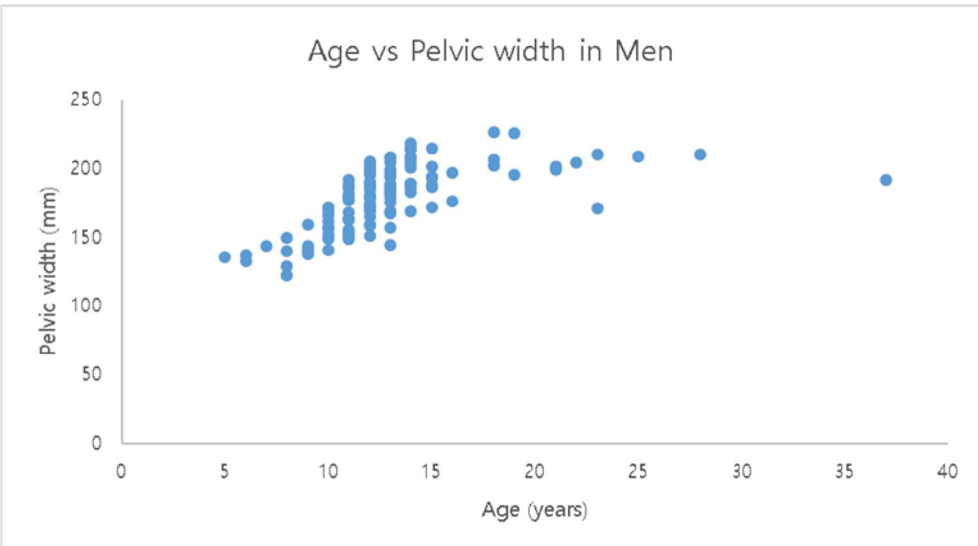

Fig. 3B. The scatter plot of age versus pelvic width in men

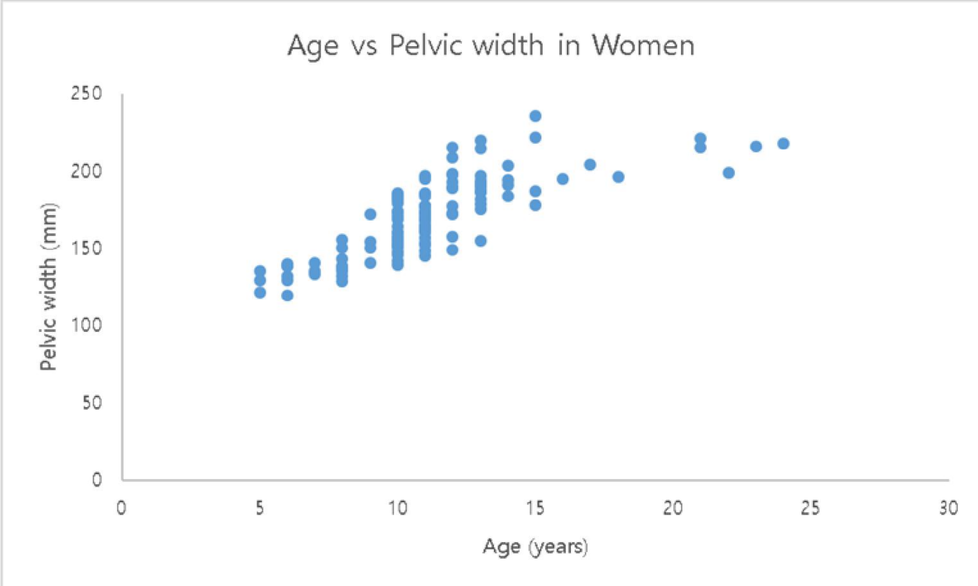

Fig. 3C. The scatter plot of age versus pelvic width in women

Discussion

In this study, the clear description of measuring LCEA was not addressed in a majority of previous literatures. Articles evidently stating the method of measuring LCEA were only 31 (18%) among the searched literature. Even including the studies citing the reference for LCEA without the specific measurement method, the number of studies which used LCEA without either the description or the citation of relevant reference were still up to 33 (19%). Considering the clinical significance of LCEA, the lack of describing precise method of measurement in those articles was surprising. For accurate understanding and comparison between studies on LCEA, the method of measuring the LCEA should be specifically explained in the manuscript. Specific methods of measurement such as whether the authors used pLCEA or gLCEA, or if they used pLCEA, what longitudinal reference line is used should be included.

For the difference between two LCEAs depending on two different longitudinal reference lines, Morscher has already explained the LCEA may be different in patients with LLD (6). He exemplified a case with a pelvic width of 250mm. However, in all the current study subjects, the pelvic width was narrower than 250mm. This may be due to the ethnical difference of East Asian population compared to the European population since some studies have reported the difference of pelvic width among different ethnic groups.(12, 13) The current study subjects showed a linear increase in pelvic width in accordance with age until 15 years of age, and then a plateaued distribution of pelvic width after that age. This was consistent with the previously reported finding that the adult size of transverse pelvis outlet is already attained by the age of approximately 15 years.(14) The correlation between gender and pelvic width showed that pelvic width was significantly greater in men by a mean of 7.5 ± 3.1 mm compared to women. This was consistent with the previous studies that found significant difference between genders.(15, 16) In estimating the dLCEA, not only the LLD but also the pelvic width is an important factor. As the pelvic width shows a wide range of distribution according to gender, age, and even just individually, the pelvic width should also be taken into consideration. Therefore, Table 2 was presented for simple and efficient clinical application of Morscher's method. For instance, the dLCEA would be estimated to be 6.8° if the LLD of 2cm is present in a patient with pelvic width of 170mm, which is common in Korean population with LLD. This would give 2.2° of difference compared to the 4.6° calculated from the same LLD of 2cm and pelvic width of 250mm.

Standard ranges of LCEA in normal adults were reported to be from 20° to 40° by Wiberg and from 23° to 44° by Jentschura.(2, 17) When pLCEA was used as LCEA, the number of patients in the current study subjects classified as acetabular undercoverage were 34 (15%) and 69 (29%) with reference to the normal range of LCEA by Wiberg and Jentschura, respectively. In contrast, if gLCEA was used, the numbers of undercoverage patients would decrease to 7 (3%) and 16 (7%) respectively. Approximately 84% (200/238) of the study patients showed dLCEA over 5° . This difference may have significant impact on the clinical decision making. As measurement error of LCEA was previously reported to be 3.1° to 4.0° ,(18) dLCEA over 5° could be a significant difference. In many patients with LLD, the pLCEA of shorter leg would be likely to be less than the normal range of LCEA. In this situation, 9.1° of difference in LCEA, which is the mean value of dLCEA of this study subjects, could be great enough to change the clinical decision for diagnosis and treatment of abnormal acetabular coverage. In these patients, whether to apply pLCEA or gLCEA could directly influence the assessment of acetabular coverage as normal or undercoverage, underlining the importance of stating the specific measurement method of LCEA.

The LCEA in patients with LLD is clinically significant in terms of acetabular undercoverage and possibility of early progression to osteoarthritis of hip.(3, 19) The hip joint forces of the shorter leg are reported to be increased by 2% and 12% in patients with LLD of 3.5cm and 6.5cm, respectively.(20) Most of other studies on patients with LLD, however, focused on the acetabular undercoverage on the longer leg.(3-5) In a study using cross-sectional survey to investigate risk factors for hip osteoarthritis, hip dysplasia (LCEA<20°) was associated with the development of osteoarthritis.(4) The other study in 2009 also showed that age, LCEA, and labral tear were associated with osteoarthritis.(5) In patients with LLD, gLCEA is theoretically always less than the pLCEA on the longer leg. The pLCEA in these patients does not essentially reflect the acetabular undercoverage on the longer leg caused by the pelvic obliquity. Therefore, in standing or walking patients, the gLCEA is intuitively more important than pLCEA in terms of hip biomechanics and arthritic change. Thus, in patients with LLD, LCEA should be measured and described as gLCEA.

Abnormal acetabular coverage on the longer side is one of the reasons why substantial LLD should be addressed. The current study showed that Morscher' s method can accurately estimate dLCEA when planning to address LLD by either shortening or lengthening procedures. As it is observed in the interobserver and intraobserver reliability test of measuring pLCEA, gLCEA, LLD, and pelvic width in this study, measurement of LLD and pelvic width is more accurate and consistent compared to that of LCEA. This is probably due to the relatively greater difference of absolute values in LCEA according to the location of landmarks. In patients with complex hip diseases or severe LLD, exact points of teardrop, center of femoral head, or lateral acetabular edge could be difficult to locate. Even with the slight change of location of those landmarks, LCEA would vary greatly which is probably the reason of relatively large reported variance of measurement in LCEA. However, in this study, LLD and pelvic width, which are easier to measure with higher ICC, were used to estimate dLCEA. In evaluating the difference of gLCEA throughout the procedures correcting LLD, the exact values of pLCEA or gLCEA are not required because pLCEA is constant and changes of gLCEA is therefore same as the change of dLCEA.

If a patient with LLD of 50mm and pelvic width of 170mm is planned for the reduction of LLD to 10mm through certain procedure, edLCEA would diminish from 17.1° to 3.4° (Table 2). Radiologically, this corresponds to the decline of pelvic obliquity in coronal plane of 13.7°. As pLCEA does not change according to pelvic obliquity, if edLCEA has diminished by 13.7°, gLCEA would be increased by 13.7° in longer leg. Therefore, it could be expected that through 40mm diminish of LLD, the patient would gain 13.7° of lateral acetabular coverage in longer leg in this patient. Likewise, even without measuring the exact pLCEA or gLCEA, the gain of gLCEA could be precisely calculated with this method.

There are several limitations of this study. First, there is an inherent possibility of a selection bias as this study was conducted as a retrospective study at a single center. Second, there is a potential magnification error in the radiographs. The tube-to-film distance of the pelvis radiographs should be 120cm with the tube vertical to the table. For all the radiographs, this tube-to-film distances are not standardized, which could lead to magnification error. However, in this study, strict criteria for the standard pelvic radiographs were applied in the exclusion process and inappropriate radiographs were excluded.(9)

In this study, literature review revealed that for past 40 years, majority of the scientific articles published in English literature involving LCEA did not describe the method of measuring LCEA. In patients with LLD, the LCEA is different according to the longitudinal reference line and it is mandatory to state measurement methods in the studies involving LCEA. The current study successfully validated Morscher's method of estimating the dLCEA. This finding could be helpful in estimating the change of LCEA before and after the limb lengthening or shortening surgery in patients with LLD.

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resonance images. Am J Obstet Gynecol. 2005;193(6):2035-40.

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80.

Supplementary Materials

Supplemenatary material 1.

("The Journal of bone and joint surgery. American volume"[Journal] OR "The Journal of bone and joint surgery. British volume"[Journal] OR "Bone & Joint Journal" OR "Clinical Orthopaedics and Related Research"[All Fields]) AND (center edge angle[Title/Abstract] OR center-edge angle[Title/Abstract] OR CEA[Title/Abstract] OR CE angle[Title/Abstract])

Supplemenatary material 2.

Studies using the longitudinal axis of the pelvis as a reference line (n = 18)			
First Author	**Publication date**	**Journal**	**LCEA measurement description**
Paterson DC.	1991	CORR	The CE angle was the angle between this line and a line perpendicular to a third line joining the inferior margins of the sacroiliac joints.
Iwase T.	1996	CORR	The angle formed between a line connecting the femoral head center and the most lateral edge of the acetabulum, and a line drawn through the femoral head center and perpendicular to the interteardrop line.
Gotoh E.	2000	CORR	Angle between the perpendicular line drawn from the superolateral edge of the acetabulum to Hilgenreiner's line and the line that connects the superolateral edge of the acetabulum and the center of the femoral head.
Wenger	2004	CORR	A horizontal line along the inferior aspect of the ischial tuberosities (Line 1). After

DE.			localization of the center of the femoral head (Line 2), a second line parallel to Line 1 was drawn through the center of the femoral head (Line 3). A line perpendicular to Line 3 was drawn through the center of the femoral head (Line 4).
Jacobson S.	2006	CORR	A line perpendicular to the teardrop line raised through the femoral head center. A second line connects the femoral head center to the lateral acetabular corner.
Troelsen A.	2008	CORR	A line from the most lateral limit of the sclerotic acetabular roof to the center of the femoral head and another line perpendicular to the line of reference and through the center of the femoral head.
Jessel RH.	2009	JBJS Am	A line drawn through the center of the femoral head and extending to the lateral edge of the sourcil (the dense bone along the lateral edge of the weight-bearing region of the acetabulum) and a line perpendicular to one joining the two femoral head centers.
Kapron AL.	2011	JBJS Am	A line perpendicular to the line connecting the ischial tuberosities and a line connecting the center of the femoral head with the lateral edge of the acetabulum.

Dolan MM.	2011	CORR	Angle between two lines: a line through the center of the femoral head perpendicular to the transverse axis of the pelvis and a line connecting the center of the femoral head to the most superolateral point of the acetabulum.
Nepple JJ.	2013	JBJS Am	Angle between a line perpendicular to the horizontal reference through the center of the femoral head and a line connecting the femoral head center to the most lateral aspect of the acetabular sourcil.
Tibor LM.	2013	CORR	A line was drawn through the center of the femoral head perpendicular to the transverse pelvic axis (interteardrop line). Another line was drawn from the center of rotation through the most superolateral point of the acetabular roof.
Monazzam S.	2013	CORR	A line was drawn connecting the right and left ischial tubercles; (2) a perfect-circle clear plastic disc was placed directly on the computer screen (Fig. 2). Using the zoom function, the femoral head was enlarged until the perfect-circle clear plastic disc matched the femoral head contour. The central hole found in the perfect-circle clear plastic disc was used to find

			the center of the femoral head; then (3) a line from the center of the femoral head that was perpendicular to the line drawn in Step 1 and a line from the center of the femoral head to the most lateral point of the acetabulum were drawn. The angle between these two lines represented the LCEA.
Tannast M.	2015	CORR	Angle formed by a line parallel to the longitudinal pelvic axis and a line connecting the center of the femoral head with the lateral edge of the acetabular sourcil.
Tannast M.	2015	CORR	Angle formed by a line parallel to the longitudinal pelvic axis and a line connecting the center of the femoral head with the lateral edge of the acetabulum.
Bouma HW.	2015	CORR	The CE angle was measured between the plane of the y-axis of the pelvis and a line from the center of a regression sphere in the acetabulum to the osseous rim of the acetabulum.
Castañeda P.	2016	CORR	The angle between two lines: (1) a line through the center of the femoral head, perpendicular to the transverse axis of the pelvis; and (2) a line through the center of the femoral head, passing through the most superolateral point of the sclerotic weightbearing zone of the

			acetabulum.
Ahn T.	2016	CORR	The LCE angle was measured using the following method: after drawing a reference line between the acetabular teardrops to correct for pelvic obliquity, a perpendicular line was drawn through the femoral head. A third line was drawn connecting the center of the femoral head to the superolateral sourcil. The angle made by the latter two lines was called the LCE angle.
Fischer CS.	2018	CORR	The center-edge angle was measured as the angle between the vertical axis of the pelvis and a line connecting the femoral head center and the lateral acetabular margin. The vertical axis of the pelvis was represented by a line connecting the center points of the femoral head of both sides. In all measurements, the center of the femoral head was assessed through the center of a best-fitting circle outlining the femoral head.

BJJ, The Bone & Joint Journal; CORR, Clinical Orthopaedics and Related Research; N/A, Not available; JBJS Am, The Journal of Bone & Joint Surgery American Volume

Studies using the line vertical to the ground as a reference line (n = 13)			
First Author	**Publication date**	**Journal**	**LCEA measurement description**
Damron TA.	1993	CORR	A vertical line through the center of the femoral head and an oblique line from head center to the lateral margin of the acetabulum.
McCarthy JJ.	1996	JBJS Am	Angle formed between a line drawn from the center of the femoral head to the outer edge of the acetabular roof and a vertical line drawn through the center of the femoral head.
Kim YJ.	2003	JBJS Am	Angle formed by a vertical line through the center of the femoral head and a line along the edge of the acetabulum.
Van de Velde S.	2006	CORR	A vertical line drawn through the center of the femoral head and a line drawn from the center through the lateral edge of the acetabular roof.
Sponseller PD.	2006	JBJS Am	The angle between a vertical line through the center of the femoral head and another line connecting the center of the femoral head with the superolateral margin of the acetabulum.

Ochoa LM.	2010	CORR	The straight vertical to the edge of the acetabular ceiling.
Monazzam S.	2013	CORR	A line from the center of the femoral head, vertically, and a line from the center of the femoral head to the lateral point of the acetabulum.
Monazzam S.	2013	CORR	A line vertical from the center of the femoral head and a line from center of the femoral head to the superior lateral edge of the acetabulum.
Schmitz MR.	2013	JBJS Am	Vertical line from the center of the femoral head and a line from the center of the femoral head to the lateral edge of the acetabulum.
Larson CM.	2015	CORR	In each vertical slice, the local acetabular center-edge angle is computed as the angle between the vertical axis and a line joining the femoral head center to the border point of the rim included in this slice.
Morris WZ.	2015	JBJS Am	The center-edge angle was then formed by a vertical line through the center of the femoral head and a line from the center of the femoral head to the lateral edge of the sourcil.
Wylie JD.	2017	CORR	The angle made by a vertical line through the center of the femoral head and a line drawn

			from the center of the femoral head through the lateral aspect of the acetabular roof (sourcil).
Wyatt M.	2017	CORR	The center of the femoral head is defined by a circle fitting the contour of the femoral head. The first branch of the angle runs perpendicular through the center of rotation. The second branch is defined by the center of the femoral head and the most lateral point of the sourcil.

BJJ, The Bone & Joint Journal; CORR, Clinical Orthopaedics and Related Research; N/A, Not available; JBJS Am, The Journal of Bone & Joint Surgery American Volume

No description of measurement method (n = 141)			
First Author	**Publication date**	**Journal**	**Description of LCEA measurement**
Fredensborg N.	1976	JBJS Br	Wiberg G. Studies on dysplastic acetabula and congenital subluxation of the hip joint: with special reference to the complication of osteo-arthritis. Acta Chir Scand. 1939:5-135.
Sutherland DH	1977	JBJS Am	N/A

Weintroub S.	1979	JBJS Am	Wiberg G. Studies on dysplastic acetabula and congenital subluxation of the hip joint: with special reference to the complication of osteo-arthritis. Acta Chir Scand. 1939:5-135.
Nakagawa M.	1980	CORR	N/A
Ninomiya S.	1984	JBJS Am	N/A
Bunch WH.	1984	JBJS Am	N/A
Hoffer MM.	1985	JBJS Am	N/A
Perlik PC.	1985	JBJS Am	N/A
Maxted MJ.	1985	JBJS Br	N/A
Graham S.	1986	CORR	N/A
Sponseller	1988	JBJS Am	Wiberg G. Studies on dysplastic acetabula and congenital subluxation of the hip joint: with

PD.			special reference to the complication of osteo-arthritis. Acta Chir Scand. 1939:5-135.
Ninomiya S.	1989	CORR	Wiberg G. Studies on dysplastic acetabula and congenital subluxation of the hip joint: with special reference to the complication of osteo-arthritis. Acta Chir Scand. 1939:5-135.
Ogata S.	1990	JBJS Br	Wiberg G. Studies on dysplastic acetabula and congenital subluxation of the hip joint: with special reference to the complication of osteo-arthritis. Acta Chir Scand. 1939:5-135.
Murphy SB.	1990	CORR	N/A
Kooijman MA.	1990	CORR	Wiberg G. Studies on dysplastic acetabula and congenital subluxation of the hip joint: with special reference to the complication of osteo-arthritis. Acta Chir Scand. 1939:5-135.
Kruse RW.	1991	JBJS Am	Wiberg G. Studies on dysplastic acetabula and congenital subluxation of the hip joint: with special reference to the complication of osteo-arthritis. Acta Chir Scand. 1939:5-135.
Albiñana J.	1995	JBJS Am	Wiberg G. Studies on dysplastic acetabula and congenital subluxation of the hip joint: with special reference to the complication of osteo-arthritis. Acta Chir Scand. 1939:5-135.

Murphy SB.	1995	JBJS Am	Wiberg G. Studies on dysplastic acetabula and congenital subluxation of the hip joint: with special reference to the complication of osteo-arthritis. Acta Chir Scand. 1939:5-135.
Root L.	1995	JBJS Am	Wiberg G. Studies on dysplastic acetabula and congenital subluxation of the hip joint: with special reference to the complication of osteo-arthritis. Acta Chir Scand. 1939:5-135.
Suda H.	1995	JBJS Br	Wiberg G. Studies on dysplastic acetabula and congenital subluxation of the hip joint: with special reference to the complication of osteo-arthritis. Acta Chir Scand. 1939:5-135.
Gordon JE.	1996	JBJS Am	N/A
Fritsch EW.	1996	CORR	Wiberg G. Studies on dysplastic acetabula and congenital subluxation of the hip joint: with special reference to the complication of osteo-arthritis. Acta Chir Scand. 1939:5-135.
Shea KG.	1997	JBJS Am	Wiberg G. Studies on dysplastic acetabula and congenital subluxation of the hip joint: with special reference to the complication of osteo-arthritis. Acta Chir Scand. 1939:5-135.
Moberg A.	1997	CORR	Wiberg G. Studies on dysplastic acetabula and congenital subluxation of the hip joint: with special reference to the complication of osteo-arthritis. Acta Chir Scand. 1939:5-135.

Schwend RM.	1999	CORR	Wiberg G. Studies on dysplastic acetabula and congenital subluxation of the hip joint: with special reference to the complication of osteo-arthritis. Acta Chir Scand. 1939:5-135.
Crockarell J Jr.	1999	CORR	Wiberg G. Studies on dysplastic acetabula and congenital subluxation of the hip joint: with special reference to the complication of osteo-arthritis. Acta Chir Scand. 1939:5-135.
Siebenrock KA.	1999	CORR	Wiberg G. The anatomy and roentgenographic appearance of a normal hip joint. Acta Chir Scand. 1939;83:7-38.
Olney B.	1999	CORR	N/A
Grudziak JS.	2001	JBJS Am	Wiberg G. Studies on dysplastic acetabula and congenital subluxation of the hip joint: with special reference to the complication of osteo-arthritis. Acta Chir Scand. 1939:5-135.
Ito H.	2001	CORR	Wiberg G. Studies on dysplastic acetabula and congenital subluxation of the hip joint: with special reference to the complication of osteo-arthritis. Acta Chir Scand. 1939:5-135.
Ko JY	2002	JBJS Am	Wiberg G. Studies on dysplastic acetabula and congenital subluxation of the hip joint: with special reference to the complication of osteo-arthritis. Acta Chir Scand. 1939:5-135.

Hasegawa Y.	2002	JBJS Am	Wiberg G. Studies on dysplastic acetabula and congenital subluxation of the hip joint: with special reference to the complication of osteo-arthritis. Acta Chir Scand. 1939:5-135.
Cashman JP.	2002	JBJS Br	Wiberg G. Studies on dysplastic acetabula and congenital subluxation of the hip joint: with special reference to the complication of osteo-arthritis. Acta Chir Scand. 1939:5-135.
Lalonde FD.	2002	CORR	Wiberg G. Studies on dysplastic acetabula and congenital subluxation of the hip joint: with special reference to the complication of osteo-arthritis. Acta Chir Scand. 1939:5-135.
Schramm M.	2003	JBJS Am	Tschauner C, Hofmann S, Czerny C. [Hip dysplasia. Morphology, biomechanics and therapeutic principles with reference to the acetabular labrum]. Orthopade , 1997;26: 89-108. German.
Yasunaga Y.	2003	JBJS Am	Wiberg G. Studies on dysplastic acetabula and congenital subluxation of the hip joint: with special reference to the complication of osteo-arthritis. Acta Chir Scand. 1939:5-135.
Hsieh PH.	2003	JBJS Am	Wiberg G. Studies on dysplastic acetabula and congenital subluxation of the hip joint: with special reference to the complication of osteo-arthritis. Acta Chir Scand. 1939:5-135.

Siebenrock KA.	2003	JBJS Am	Wiberg G. The anatomy and roentgenographic appearance of a normal hip joint. Acta Chir Scand. 1939;83:7-38.
Schramm M.	2004	JBJS Am	N/A
Ito H.	2004	JBJS Am	Wiberg G. Studies on dysplastic acetabula and congenital subluxation of the hip joint: with special reference to the complication of osteo-arthritis. Acta Chir Scand. 1939:5-135.
Macnicol ME.	2004	JBJS Br	Wiberg G. Studies on dysplastic acetabula and congenital subluxation of the hip joint with special reference to the complication of osteoarthritis. JAMA 1940;115:81.
Kawate K.	2004	CORR	Wiberg G. Studies on dysplastic acetabula and congenital subluxation of the hip joint: with special reference to the complication of osteo-arthritis. Acta Chir Scand. 1939:5-135.
Migaud H.	2004	CORR	N/A
Clohisy JC.	2005	JBJS Am	Wiberg G. Studies on dysplastic acetabula and congenital subluxation of the hip joint: with special reference to the complication of osteo-arthritis. Acta Chir Scand. 1939:5-135.

Lipton GE.	2005	CORR	Wiberg G. Studies on dysplastic acetabula and congenital subluxation of the hip joint: with special reference to the complication of osteo-arthritis. Acta Chir Scand. 1939:5-135.
Miller NH.	2005	CORR	Wiberg G. Studies on dysplastic acetabula and congenital subluxation of the hip joint: with special reference to the complication of osteo-arthritis. Acta Chir Scand. 1939:5-135.
Yasunaga Y.	2006	JBJS Am	N/A
Clohisy JC.	2006	JBJS Am	N/A
Peters CL.	2006	JBJS Am	Wiberg G. Studies on dysplastic acetabula and congenital subluxation of the hip joint: with special reference to the complication of osteo-arthritis. Acta Chir Scand. 1939:5-135.
Guevara CJ.	2006	CORR	Renner C. Die Shenton-Linie. Zentralbl Chir. 1925;52:2875-2876
Roush TF.	2006	CORR	Wiberg G. Shelf operation in congenital dysplasia of the acetabulum and in subluxation and dislocation of the hip. J Bone Joint Surg Am. 1953;35: 65-80.

Yasunaga Y.	2007	JBJS Am	N/A
Clohisy JC.	2007	JBJS Am	Wiberg G. The anatomy and roentgenographic appearance of a normal hip joint. Acta Chir Scand. 1939;83:7-38.
Nehme A.	2007	CORR	Wiberg G. Studies on dysplastic acetabula and congenital subluxation of the hip joint: with special reference to the complication of osteo-arthritis. Acta Chir Scand. 1939:5-135.
Ito H.	2007	CORR	Wiberg G. Studies on dysplastic acetabula and congenital subluxation of the hip joint: with special reference to the complication of osteo-arthritis. Acta Chir Scand. 1939:5-135.
Hasegawa Y.	2007	CORR	Wiberg G. Studies on dysplastic acetabula and congenital subluxation of the hip joint: with special reference to the complication of osteo-arthritis. Acta Chir Scand. 1939:5-135.
Nakamura Y.	2007	CORR	Wiberg G. Studies on dysplastic acetabula and congenital subluxation of the hip joint: with special reference to the complication of osteo-arthritis. Acta Chir Scand. 1939:5-135.
Maeyama	2008	JBJS Am	Wiberg G. Studies on dysplastic acetabula and congenital subluxation of the hip joint: with

A.			special reference to the complication of osteo-arthritis. Acta Chir Scand. 1939:5-135.
Ranade A.	2008	CORR	Wiberg G. Studies on dysplastic acetabula and congenital subluxation of the hip joint: with special reference to the complication of osteo-arthritis. Acta Chir Scand. 1939:5-135.
Troelsen A.	2008	CORR	Wiberg G. Studies on dysplastic acetabula and congenital subluxation of the hip joint: with special reference to the complication of osteo-arthritis. Acta Chir Scand. 1939:5-135.
Fuchs-Winkelmann S.	2008	CORR	Wiberg G. Studies on dysplastic acetabula and congenital subluxation of the hip joint: with special reference to the complication of osteo-arthritis. Acta Chir Scand. 1939:5-135.
Steppacher SD.	2008	CORR	Wiberg G. The anatomy and roentgenographic appearance of a normal hip joint. Acta Chir Scand. 1939;83:7-38.
Mavcic B.	2008	CORR	N/A
Anderson LA.	2009	JBJS Am	N/A

Sierra RJ.	2010	JBJS Am	Wiberg G. Studies on dysplastic acetabula and congenital subluxation of the hip joint: with special reference to the complication of osteo-arthritis. Acta Chir Scand. 1939:5-135.
Thawrani D.	2010	JBJS Am	N/A
Kobayashi D.	2010	JBJS Am	Wiberg G. Studies on dysplastic acetabula and congenital subluxation of the hip joint: with special reference to the complication of osteo-arthritis. Acta Chir Scand. 1939:5-135.
Teratani T.	2010	JBJS Am	Wiberg G. Studies on dysplastic acetabula and congenital subluxation of the hip joint: with special reference to the complication of osteo-arthritis. Acta Chir Scand. 1939:5-135.
Teratani T.	2011	JBJS Am	N/A
Sankar WN.	2011	JBJS Am	Wiberg G. Studies on dysplastic acetabula and congenital subluxation of the hip joint: with special reference to the complication of osteo-arthritis. Acta Chir Scand. 1939:5-135.
Kappe T.	2011	CORR	Wiberg G. Studies on dysplastic acetabula and congenital subluxation of the hip joint: with special reference to the complication of osteo-arthritis. Acta Chir Scand. 1939:5-135.

Karashima H.	2011	CORR	Wiberg G. Studies on dysplastic acetabula and congenital subluxation of the hip joint: with special reference to the complication of osteo-arthritis. Acta Chir Scand. 1939:5-135.
Colvin AC.	2011	CORR	Wiberg G. Studies on dysplastic acetabula and congenital subluxation of the hip joint: with special reference to the complication of osteo-arthritis. Acta Chir Scand. 1939:5-135.
Mast NH.	2011	CORR	Wiberg G. Studies on dysplastic acetabula and congenital subluxation of the hip joint: with special reference to the complication of osteo-arthritis. Acta Chir Scand. 1939:5-135.
Beaulé PE	2012	CORR	Wiberg G. Studies on dysplastic acetabula and congenital subluxation of the hip joint: with special reference to the complication of osteo-arthritis. Acta Chir Scand. 1939:5-135.
Lehmann CL.	2012	CORR	Wiberg G. Studies on dysplastic acetabula and congenital subluxation of the hip joint: with special reference to the complication of osteo-arthritis. Acta Chir Scand. 1939:5-135.
Yasunaga Y.	2012	CORR	N/A

Clohisy JC.	2012	CORR	Wiberg G. Studies on dysplastic acetabula and congenital subluxation of the hip joint: with special reference to the complication of osteo-arthritis. Acta Chir Scand. 1939:5-135.
Tannast M.	2012	CORR	N/A
Hartig-Andreasen C.	2012	CORR	Wiberg G. Studies on dysplastic acetabula and congenital subluxation of the hip joint: with special reference to the complication of osteo-arthritis. Acta Chir Scand. 1939:5-135.
Ross JR.	2012	CORR	Wiberg G. Studies on dysplastic acetabula and congenital subluxation of the hip joint: with special reference to the complication of osteo-arthritis. Acta Chir Scand. 1939:5-135.
De La Rocha A.	2012	CORR	Wiberg G. Studies on dysplastic acetabula and congenital subluxation of the hip joint: with special reference to the complication of osteo-arthritis. Acta Chir Scand. 1939:5-135.
Yoo WJ.	2012	CORR	Wiberg G. Studies on dysplastic acetabula and congenital subluxation of the hip joint: with special reference to the complication of osteo-arthritis. Acta Chir Scand. 1939:5-135.
Polkowski	2012	CORR	Wiberg G. Studies on dysplastic acetabula and congenital subluxation of the hip joint: with

GG.			special reference to the complication of osteo-arthritis. Acta Chir Scand. 1939:5-135.
Podeszwa DA.	2013	CORR	Wiberg G. Studies on dysplastic acetabula and congenital subluxation of the hip joint: with special reference to the complication of osteo-arthritis. Acta Chir Scand. 1939:5-135.
Monazzam S.	2013	CORR	Wiberg G. Studies on dysplastic acetabula and congenital subluxation of the hip joint: with special reference to the complication of osteo-arthritis. Acta Chir Scand. 1939:5-135.
Stelzeneder D.	2013	CORR	Wiberg G. Studies on dysplastic acetabula and congenital subluxation of the hip joint: with special reference to the complication of osteo-arthritis. Acta Chir Scand. 1939:5-135.
Maruyama M.	2013	CORR	Wiberg G. Studies on dysplastic acetabula and congenital subluxation of the hip joint: with special reference to the complication of osteo-arthritis. Acta Chir Scand. 1939:5-135.
Kaneko H.	2014	BJJ	Wiberg G. Studies on dysplastic acetabula and congenital subluxation of the hip joint with special reference to the complication of osteoarthritis. JAMA 1940;115:81.
Tarassoli P.	2014	BJJ	Wiberg G. Studies on dysplastic acetabula and congenital subluxation of the hip joint with special reference to the complication of osteoarthritis. JAMA 1940;115:81.

Novais EN.	2014	CORR	Wiberg G. Studies on dysplastic acetabula and congenital subluxation of the hip joint: with special reference to the complication of osteo-arthritis. Acta Chir Scand. 1939:5-135.
Novais EN.	2014	CORR	Wiberg G. Studies on dysplastic acetabula and congenital subluxation of the hip joint: with special reference to the complication of osteo-arthritis. Acta Chir Scand. 1939:5-135.
Diesel CV.	2015	BJJ	Wiberg G. Studies on dysplastic acetabula and congenital subluxation of the hip joint: with special reference to the complication of osteo-arthritis. Acta Chir Scand. 1939:5-135.
Hingsammer AM.	2015	CORR	N/A
Nardo L.	2015	CORR	Wiberg G. Studies on dysplastic acetabula and congenital subluxation of the hip joint: with special reference to the complication of osteo-arthritis. Acta Chir Scand. 1939:5-135.
Duncan ST.	2015	CORR	Wiberg G. The anatomy and roentgenographic appearance of a normal hip joint. Acta Chir Scand. 1939;83:7-38.
Clohisy JC.	2015	CORR	Wiberg G. Studies on dysplastic acetabula and congenital subluxation of the hip joint: with

			special reference to the complication of osteo-arthritis. Acta Chir Scand. 1939:5-135.
Stambough JB.	2015	CORR	Wiberg G. Studies on dysplastic acetabula and congenital subluxation of the hip joint: with special reference to the complication of osteo-arthritis. Acta Chir Scand. 1939:5-135.
Fujji M.	2015	CORR	Wiberg G. Studies on dysplastic acetabula and congenital subluxation of the hip joint: with special reference to the complication of osteo-arthritis. Acta Chir Scand. 1939:5-135.
Ross JR.	2015	CORR	Wiberg G. Studies on dysplastic acetabula and congenital subluxation of the hip joint: with special reference to the complication of osteo-arthritis. Acta Chir Scand. 1939:5-135.
Kobayashi D.	2015	CORR	Wiberg G. Studies on dysplastic acetabula and congenital subluxation of the hip joint: with special reference to the complication of osteo-arthritis. Acta Chir Scand. 1939:5-135.
Steppacher SD.	2015	CORR	N/A
Beaulé PE	2015	CORR	Wiberg G. Studies on dysplastic acetabula and congenital subluxation of the hip joint: with special reference to the complication of osteo-arthritis. Acta Chir Scand. 1939:5-135.

Ollivier M.	2016	JBJS Am	N/A
Matheney T.	2016	JBJS Am	Wiberg G. The anatomy and roentgenographic appearance of a normal hip joint. Acta Chir Scand. 1939;83:7-38.
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Shin CH.	2016	CORR	Wiberg G. Studies on dysplastic acetabula and congenital subluxation of the hip joint: with special reference to the complication of osteo-arthritis. Acta Chir Scand. 1939:5-135.
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Carsi MB.	2016	CORR	N/A
Grammatopoulos G.	2016	CORR	N/A
Patel JH.	2017	JBJS Am	Wiberg G. Studies on dysplastic acetabula and congenital subluxation of the hip joint: with special reference to the complication of osteo-arthritis. Acta Chir Scand. 1939:5-135.
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Nepple JJ.	2017	CORR	Wiberg G. Studies on dysplastic acetabula and congenital subluxation of the hip joint: with special reference to the complication of osteo-arthritis. Acta Chir Scand. 1939:5-135.
Wells J.	2017	CORR	Wiberg G. Studies on dysplastic acetabula and congenital subluxation of the hip joint: with special reference to the complication of osteo-arthritis. Acta Chir Scand. 1939:5-135.

Novais EN.	2017	CORR	Wiberg G. Studies on dysplastic acetabula and congenital subluxation of the hip joint: with special reference to the complication of osteo-arthritis. Acta Chir Scand. 1939:5-135.
Anderson LA.	2017	CORR	N/A
Goronzy J.	2017	CORR	Wiberg G. The anatomy and roentgenographic appearance of a normal hip joint. Acta Chir Scand. 1939;83:7-38.
Wyles CC.	2017	CORR	Wiberg G. Studies on dysplastic acetabula and congenital subluxation of the hip joint: with special reference to the complication of osteo-arthritis. Acta Chir Scand. 1939:5-135.
Wells J.	2018	JBJS Am	Wiberg G. Studies on dysplastic acetabula and congenital subluxation of the hip joint: with special reference to the complication of osteo-arthritis. Acta Chir Scand. 1939:5-135.
Novais EN.	2018	JBJS Am	Wiberg G. The anatomy and roentgenographic appearance of a normal hip joint. Acta Chir Scand. 1939;83:7-38.
Rajan PV.	2018	BJJ	N/A

Morita D.	2018	CORR	Wiberg G. Studies on dysplastic acetabula and congenital subluxation of the hip joint: with special reference to the complication of osteo-arthritis. Acta Chir Scand. 1939:5-135.
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Tachibana T.	2019	CORR	Wiberg G. Studies on dysplastic acetabula and congenital subluxation of the hip joint: with special reference to the complication of osteo-arthritis. Acta Chir Scand. 1939:5-135.
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Putnam SM.	2019	CORR	Wiberg G. Studies on dysplastic acetabula and congenital subluxation of the hip joint: with special reference to the complication of osteo-arthritis. Acta Chir Scand. 1939:5-135.
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Chou DTS.	2019	CORR	Wiberg G. Studies on dysplastic acetabula and congenital subluxation of the hip joint: with special reference to the complication of osteo-arthritis. Acta Chir Scand. 1939:5-135.

Wells J.	2019	CORR	Wiberg G. Studies on dysplastic acetabula and congenital subluxation of the hip joint: with special reference to the complication of osteo-arthritis. Acta Chir Scand. 1939:5-135.
McClincy MP.	2019	CORR	Wiberg G. The anatomy and roentgenographic appearance of a normal hip joint. Acta Chir Scand. 1939;83:7-38.
Novais EN.	2019	CORR	Wiberg G. Studies on dysplastic acetabula and congenital subluxation of the hip joint: with special reference to the complication of osteo-arthritis. Acta Chir Scand. 1939:5-135.

BJJ, The Bone & Joint Journal; JBJS Br, The Journal of Bone & Joint Surgery British Volume; JBJS Am, The Journal of Bone & Joint Surgery American Volume; CORR, Clinical Orthopaedics and Related Research; N/A, Not available

초 록

하지 부동이 외측 중심비구각 측정의 차이에 미치는 영향

서론

외측 중심비구각은 널리 대퇴골두의 비구 피복을 측정하기 위하여 널리 사용되는 방사선학적 지표이다. 하지 부동이 있는 환자들에서는 관상면에서의 골반 경사로 인하여 어떠한 세로 기준선을 사용하였는지에 따라 외측 중심비구각이 다르게 측정된다. 이 연구에서는 과거 문헌에서 어떠한 기준선이 사용되었는지 조사하고, 하지 부동 환자들에서 세로 기준선에 따른 외측 중심 비구각의 차이를 추정하기 위한 Morscher의 방법을 검증하고자 한다.

본론

1976년 1월부터 2019년 7월까지 MEDLINE 데이터베이스에서 LCEA와 관련된 임상연구를 검색하여 사용된 세로 기준선에 따라 분류하였다. 2004년 1월부터 2019년 7월 23일까지 하지 부동에 대해 수술적 치료를 받은 238명의 환자들이 연구에 포함되었다. 외측 중심비구각은 기립 골반 전후방 일반 방사선영상에서 짧은 다리에서 서로 다른 두 세로 기준선 - 골반의 세로축 (pLCEA)과 지면에 수직인 선 (gLCEA)을 사용하여 측정하였고 두 외측 중심비구각의 차이 (dLCEA)를 계산하였다. 또한 dLCEA를 같은 방사선 영상에서 측정된 골반 넓이와 하지 길이 차이를 대입한 Morscher의 삼각함수 식을 사용하여 추정하였다. 위의 방법으로 측정한 dLCEA와 추정한 dLCEA를 비교하였다.

172건의 문헌 중에서 pLCEA와 gLCEA는 각각 18 (10%)와 13 (8%)건의 연구에서 사용되었다. 108 (63%)개의 연구에서는 외측

중심비구각의 측정방법을 구체적으로 기술하지 않았으나 관련된 참고문헌을 인용하였다. 반면, 33 (19%) 건의 연구에서는 외측 중심비구각의 측정방법과 참고문헌의 인용 모두 제시하지 않았다. pLCEA(26.8 ± 6.8°, [range, 2.6° to 52.2°]) 와 gLCEA (36.0 ± 8.0°, [range, 8.2° to 58.2°])는 평균 9.1 ± 4.6° [range, 0.7° to 26.1°]의 dLCEA로 통계적으로 유의한 차이를 보였다. 연구 환자들의 골반 넓이는 174.3 ± 24.3mm (range, 120.0 to 235.8mm)였으며 15세까지는 연령에 대한 선형적인 증가를 보였다. Morscher의 방법으로 추정한 dLCEA의 평균값은 9.2 ± 4.6° [range, 1.0° to 26.1°]였으며 측정한 dLCEA와 유의한 통계적 차이는 발견할 수 없었다 (p=0.433).

결론

하지 부동 환자에서 pLCEA와 gLCEA가 차이를 보이기 때문에 외측 중심비구각을 측정하기 위해 어떠한 세로 기준선이 사용되었는지가 논문에 제시되어야한다. 하지 부동 환자에서 dLCEA를 추정하는 Morscher의 방법은 성공적으로 검증되었다. 이러한 정보는 하지 부동 환자의 치료 시 하지 길이 차이와 골반 넓이를 이용하여 외측 중심비구각의 변화를 추정하는데 사용될 수 있을 것이다.

주요어 : 하지부동, 외측 중심비구각, 통계적 검증

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